2017-03

CREATE: Enabling Innovation through Computational Prototypes and Supercomputers

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Monterey, California. Naval Postgraduate School

Enabling Innovation through Computational Prototypes and Supercomputers

14th NPS Acquisition Research Symposium, Monterey, CA
April 26-27, 2017

Dr. Douglass Post, HCPMP CREATE Associate Director

HPCMP Ecosystem

Users

A technology-led, innovation-focused program committed to extending HPC to address the DoD's most significant challenges

DoD Supercomputing Resource Centers (DSRCs)

(DSRCs)

U.S. Air Force Research Laboratory DSRC

U.S. Army Research Laboratory DSRC

U.S. Army Engineer Research and Development Center DSRC

Maui High Performance Computing Center DSRC

U.S. Navy DSRC

Networking and Security

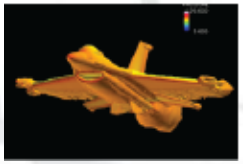
Defense Research & Engineering Network (DREN)

Computer Network Defense, Security R&D, and Security Integration

Software Applications

Core Software

Computational Environments

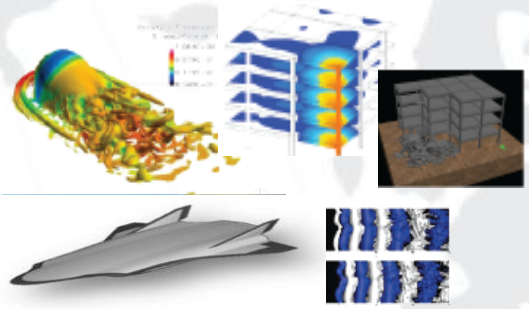


Education and Training

HPC User Support

Results

Science and Technology

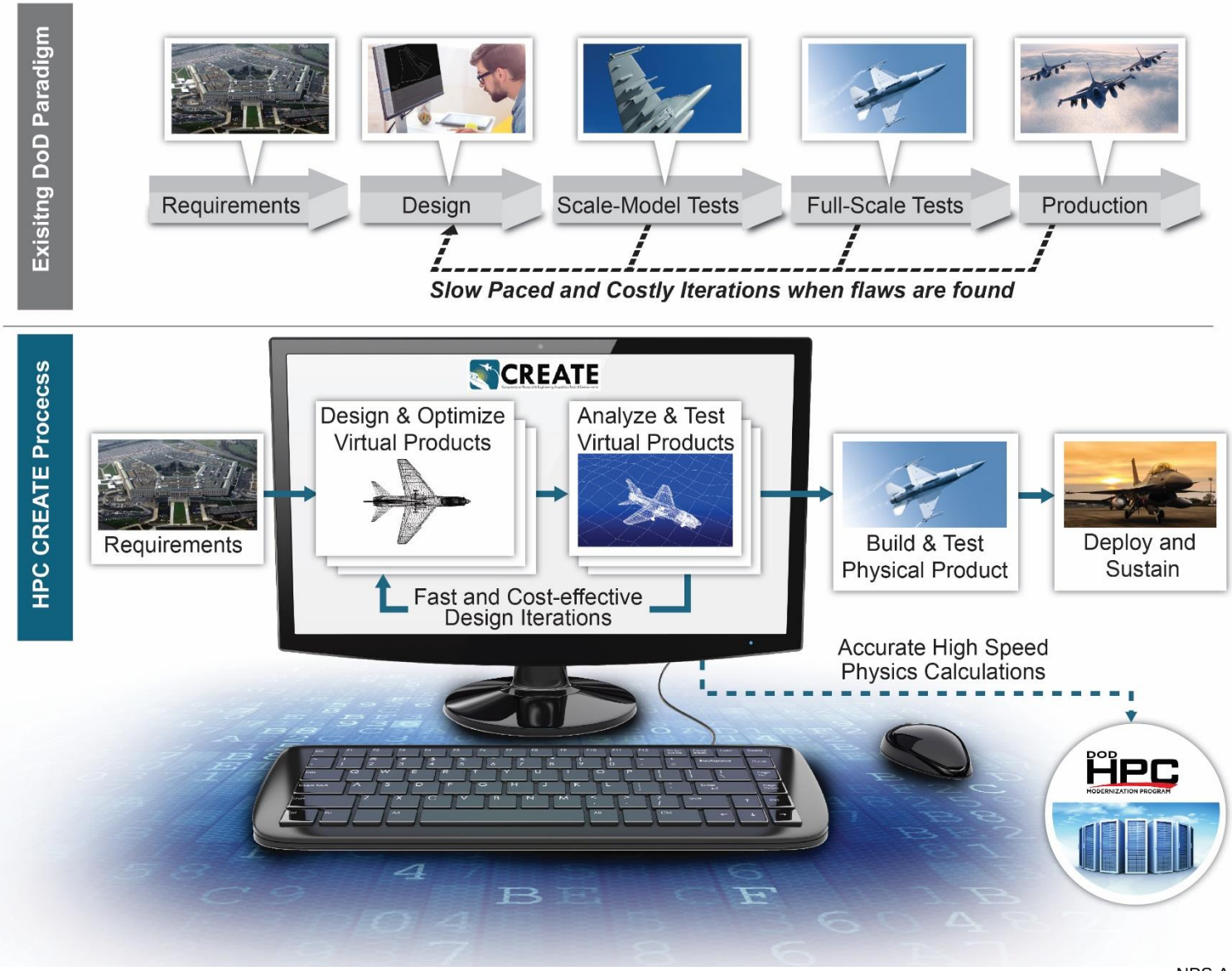


Test and Evaluation

Acquisition Engineering

Innovation with Computational Prototyping and HPC

Try, Fail, and Fix early and Often, Before You Cut Metal!



CREATE 5 Projects: 11 Multi-Physics Software Tools

- **Air Vehicles—CREATE-AV**
  - DaVinci - Rapid conceptual design
  - Kestrel - High-fidelity, full-vehicle, multi-physics analysis tool for fixed-wing aircraft
  - Helios - High-fidelity, full-vehicle, multi-physics analysis tool for rotary-wing aircraft
- **Ships—CREATE-Ships**
  - Rapid Ship Design Environment (RSDE) - Rapid Design and Synthesis Capability
  - Navy Enhanced Sierra Mechanics (NESM) - Ship Shock & Shock Damage Assessment
  - NAVYFOAM - Ship Hydrodynamics — predicts hydrodynamic performance
  - Integrated Hydro Design Environment (IHDE) - Facilitates access to naval design tools
- **RF Antenna—CREATE-RF**
  - SENTRI - Electromagnetics antenna design integrated with platforms
- **Ground Vehicles—CREATE-GV**
  - Mercury – High-fidelity, multi-physics simulation tool for vehicle systems and components
  - Mobility Analysis Tool (MAT) – Analysis tool to evaluate ground vehicle performance metrics
- **Meshing and Geometry—CREATE-MG**
  - Capstone - Components for generating geometries and meshes needed for analysis

CREATE-AV
Aircraft (AV) Design Tools

CREATE-SHIPS
Ship Design Tools

CREATE-RF
Radio Frequency (RF) Antenna Design and Integration Tools

CREATE-GV
Ground Vehicle Design Tools

CREATE-MG
Meshing and Geometry (MG) Support

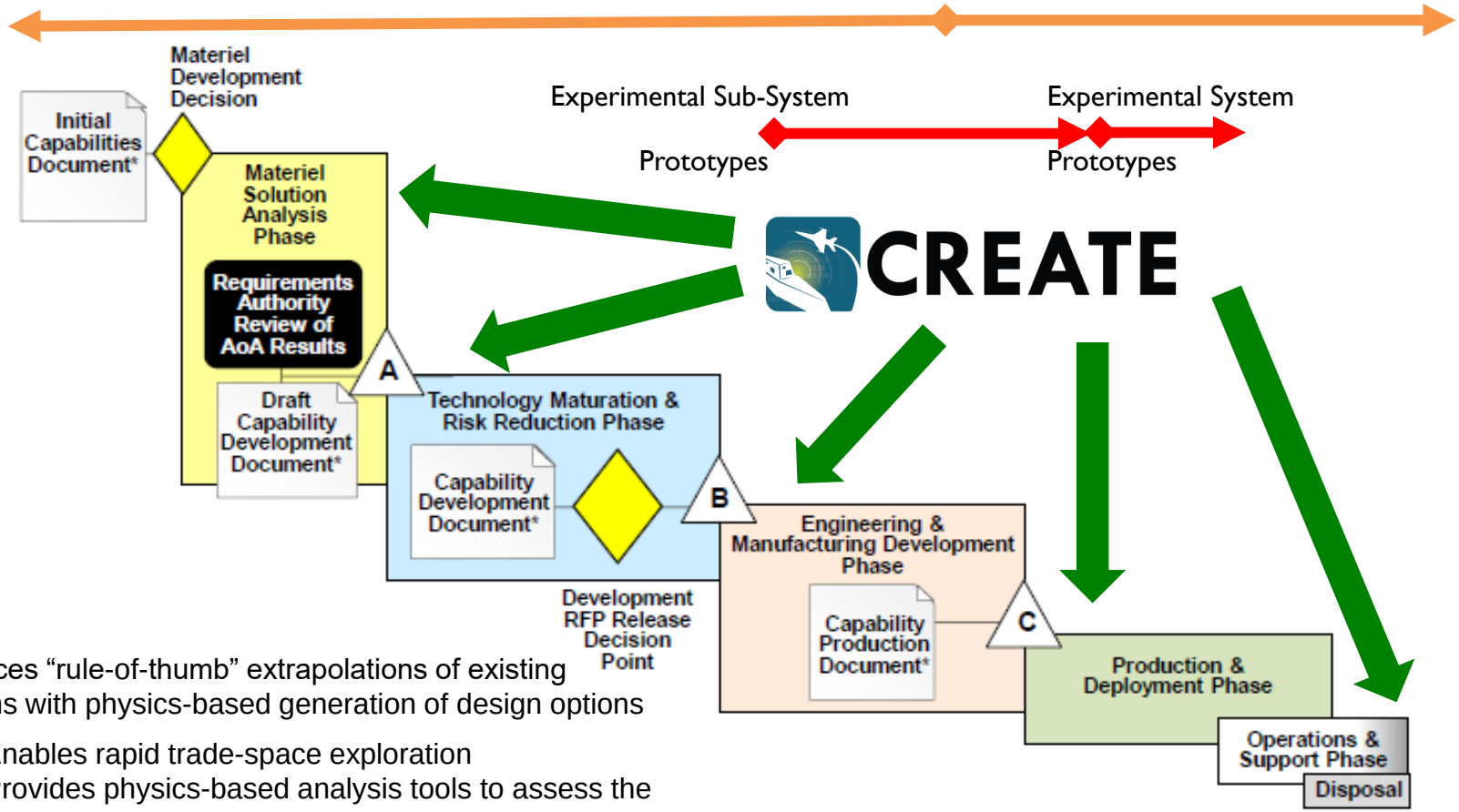
160+ user orgs
- 50% industry
- 40% government
- 10% other

- >1000 licenses
- 70+ programs

CREATE reduces risk, increases decision space, and supports accelerated production schedules

CREATE: Agility for the Acquisition Cycle

Physics-based Computing Tests of Computational Prototypes—Moves "Testing to the Left (and Right)"



- Replaces "rule-of-thumb" extrapolations of existing designs with physics-based generation of design options
  - Enables rapid trade-space exploration
  - Provides physics-based analysis tools to assess the feasibility of the design options
- CREATE augments "failure data from live tests" with "predictions of computational prototype performance," providing timely decision data that identifies design flaws and performance shortfalls early, allowing them to be fixed before metal is cut

CREATE Tools Impacting DoD Programs

DOD HPC MODERNIZATION PROGRAM

NAVSEA

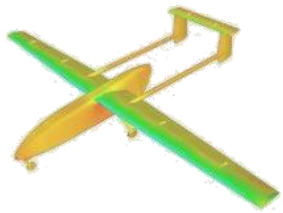
DDG-1000

CVN-78 Class

Ohio SSBN Replacement

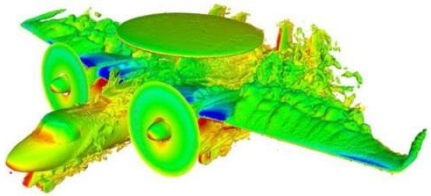
LX(R)

NAVAIR



Aerostar & Raven UAVs

F/A-18 E/F/G

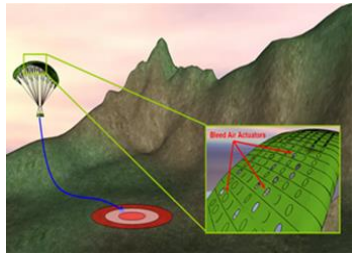


E-2D

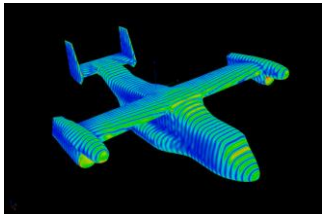
ARMY/USMC

UH-60

CH-47 (ACRB)



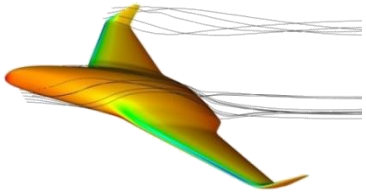
Guided Airdrop (RDECOM)



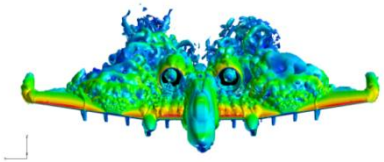
V-22

AFLCMC

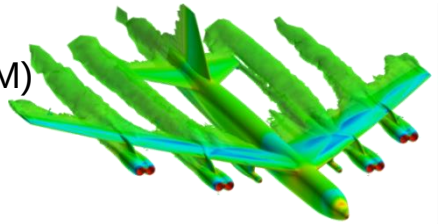
F-15 SA/DB-110



Strategic Airlift CP&A



A-10



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HPCMP CREATE™ – AV Kestrel

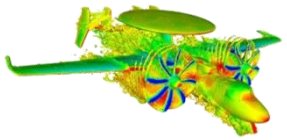
- **Kestrel is the Fixed-Wing product of the CREATE™ AV program**
  - Multi-mesh/multi-solver paradigm
    - Unstructured near-body
    - High order Cartesian off-body
    - Adaptive Mesh Refinement
    - Fast overset connectivity
  - Full spectrum of aircraft types

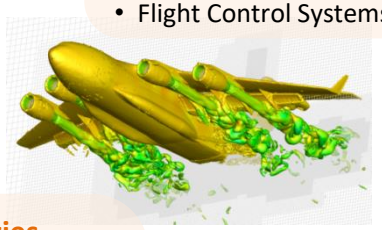
    Fighter, Bomber, Tanker, Transport, UAV
  - Full spectrum of flight conditions and missions
    - Low-speed, transonic, supersonic
    - Cruise, maneuver, take-off/land, refueling, formation flight, store carriage and release, pilot ejection, precision air-drop, and more…

Kestrel Version 7

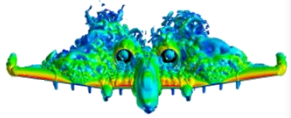
Capabilities

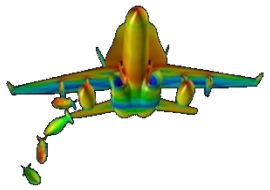
High fidelity coupled physics
- Aerodynamics
- Structural Dynamics
- Propulsion
- Flight Control Systems





Key Technologies
- Multi-mesh paradigm
- Adaptive mesh refinement
- High order Cartesian solver
- Python-based common software infrastructure
- Generalized interface for externally developed “plug-in” capability modules

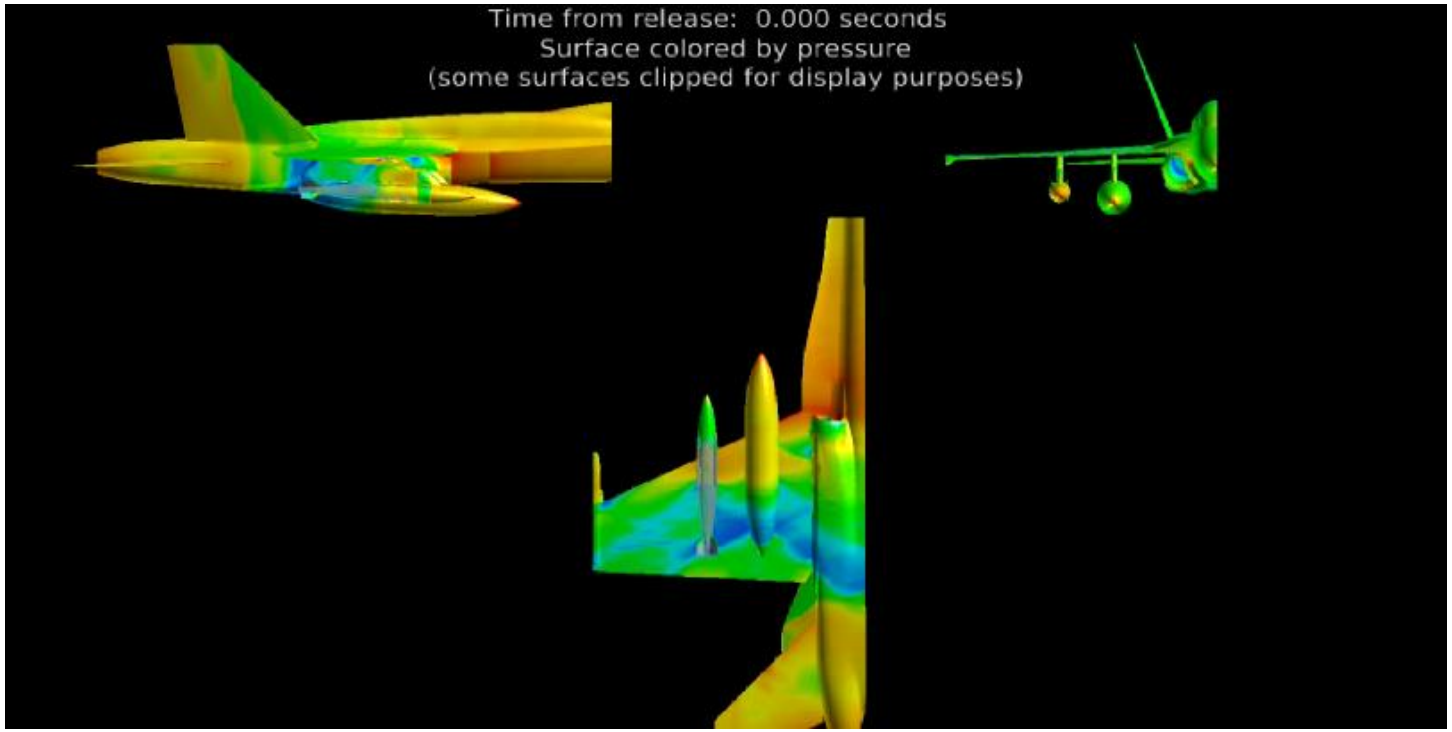




Expanding Footprint of Kestrel Adoption
- 391 active license holders (as of 30 Sep 2016)
- 21 Defense Orgs (Labs, Engineering and Test Centers) actively using Kestrel
- All major manufacturers actively evaluating Kestrel
- 5 Orgs affiliated with Other Federal Agencies using Kestrel to support US Gov’t Programs
- 4 select US Academic Institutions and the Service Academies using Kestrel to support DoD Programs

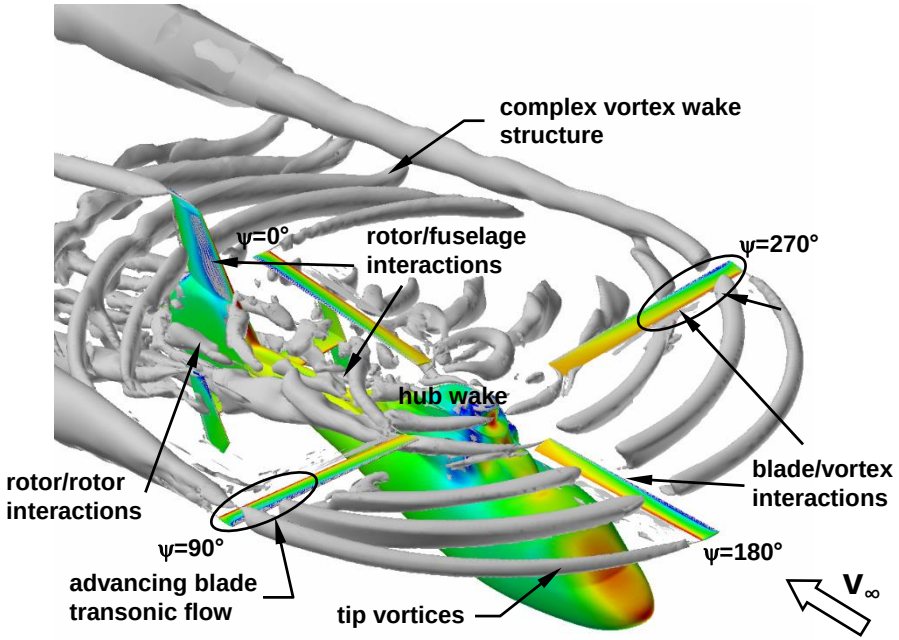
Store Separation Analysis

- **DoD fighter/bomber aircraft programs have a huge set of combinatorials for aircraft/store clearance in flight test**
- **Coupled store separation capability is critical to early discovery of issues**
  - Multi-body static interference “matrix” analysis
  - Multi-body overset mesh relative motion/collision detection

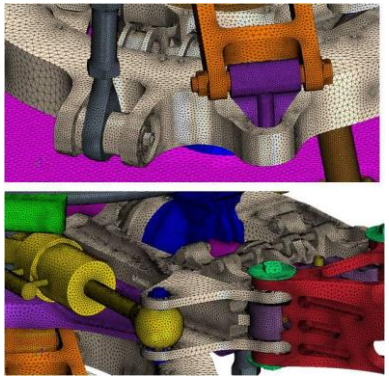


Helios Technology Targets

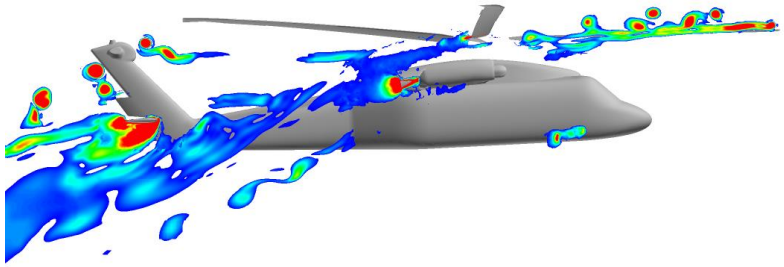
- **Fluid-structure coupling**
  - Rotor blade aeroelastic motion
  - Trim and pilot controls
- **Complex fluid dynamics**
  - Highly unsteady flowfield
  - Shock waves on advancing rotor
  - Dynamic stall on retreating rotor
- **Interactional aerodynamics**
  - Rotor/fuselage, main rotor/tail rotor
- **Other complexities**
  - Complex geometry
  - Bodies in relative motion



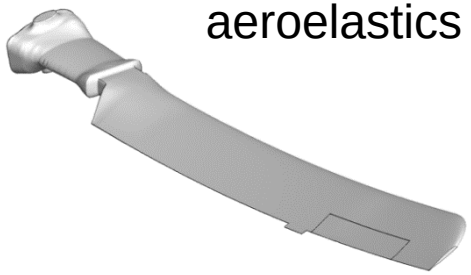
aeromechanics challenges



complex geometry



interactional aerodynamics



aeroelastics

CREATE-AV "Helios" Support for Army Joint Multi-Role (JMR) Technology Demonstrator

Karem

Bell

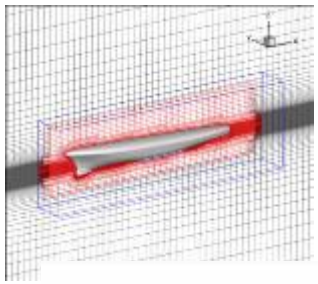
AVX

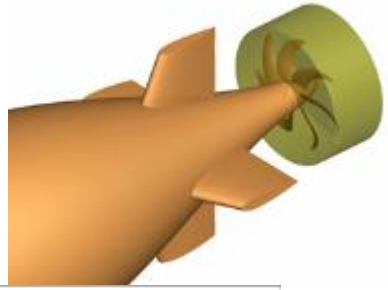
Sikorsky/ Boeing

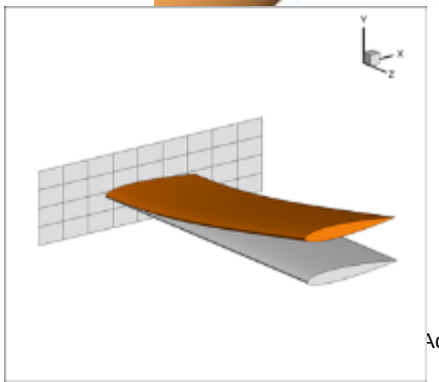
- JMR is the Army's science and technology effort for the Future Vertical Lift (FVL) program of record
  - FVL goal is to field speedy, long-range successors to the Army's helicopter fleets
- In June 2014, Army engineers used CREATE-AV Helios help evaluate the full-vehicle aeromechanics designs from the four initial JMR industry partners
- The Bell and Sikorsky/Boeing designs were chosen to move forward to technology demonstration in 2017
- Government and US industry engineering teams are currently using Helios to model performance and interactional aerodynamics effects for both of these designs

NavyFOAM Features and Capabilities
NSWC Carderock / CREATE

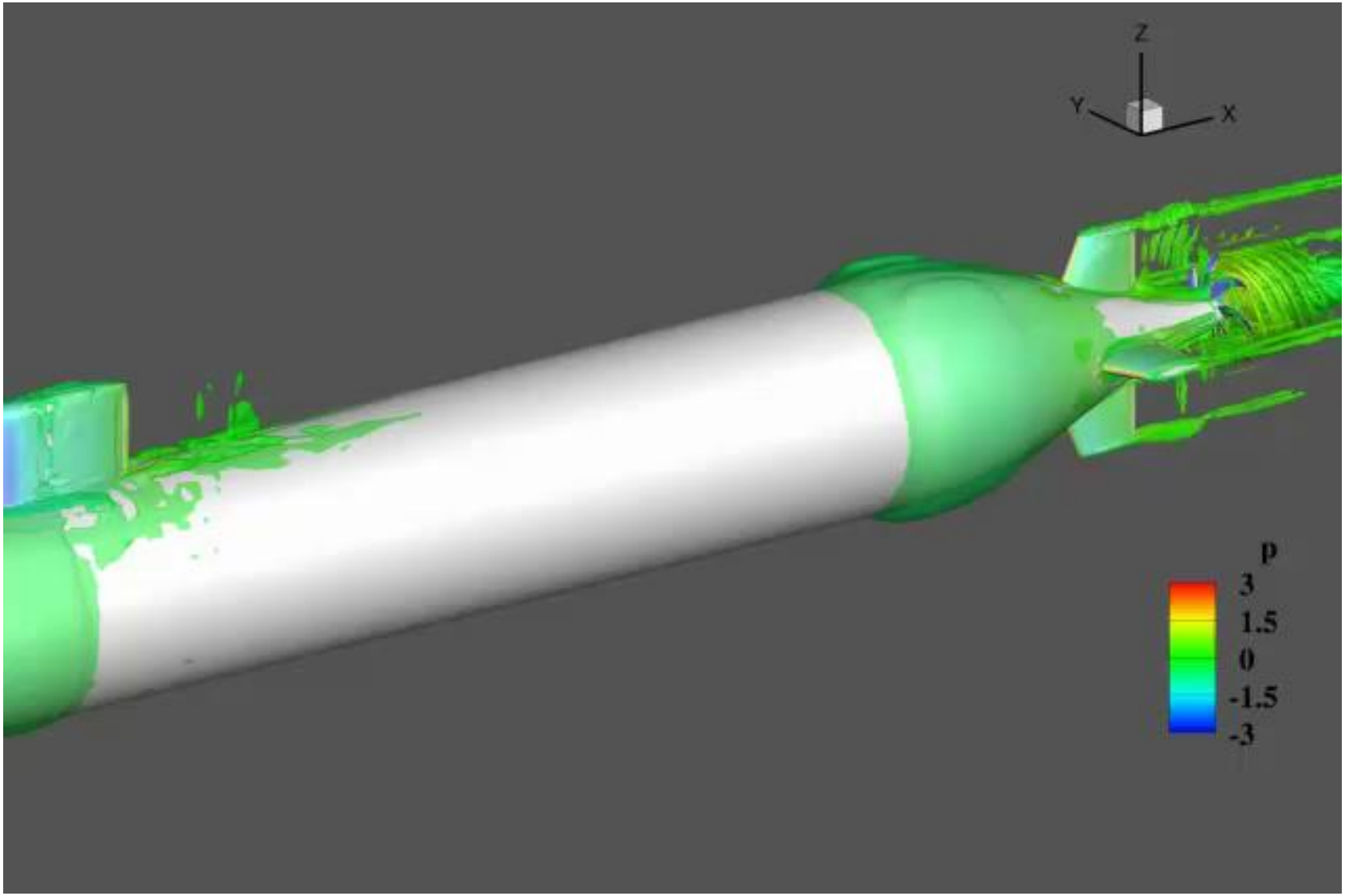
- **Numerical wave tank**
- Finite-volume discretization for arbitrary polyhedral (unstructured) grids
- Implicit/semi-implicit projection method for incompressible and compressible flows
- RANS, LES, and hybrid URANS/LES turbulence model suite
- GCL-compliant ALE method for moving/deforming grids
- Coupled 6-DOF rigid-body dynamics (RBD) and CFD solutions
- Overlaid-grids
- Sliding-grids & Multiple Rotating Frames (MRF)
- Free-surface-capturing using volume-of-fluid (VOF) method
- Stratified flows
- Cavitating flows
- Fluid structure interaction







Crashback Simulation

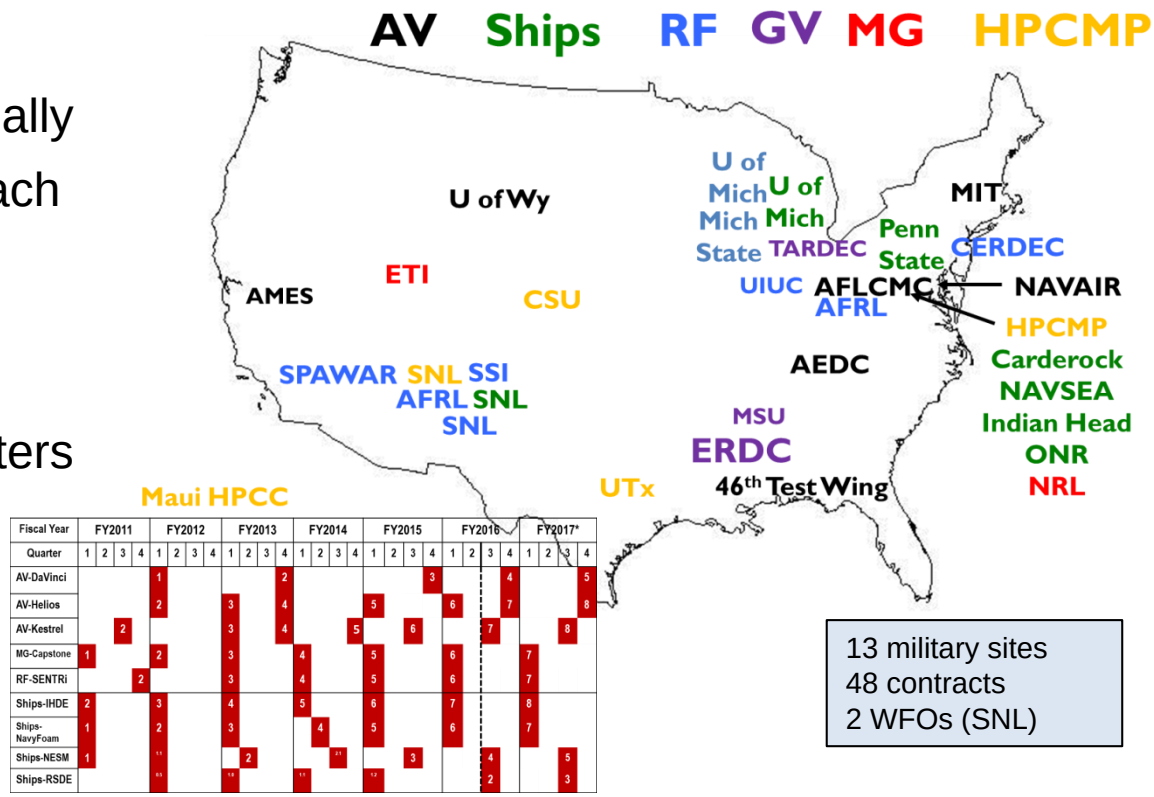


Build the Right Software, and Build it Right!

- **Software built by government-led teams of 5 to 10 staff**
  - **Technical team and team leader embedded in customer organizations**
  - **Optimal balance of team agility, structured process, and accountability**
- **Highly Disciplined Software Development Processes**
  - **Strong emphasis on software quality and accountability**
  - **Supportive code development environment—virtual clusters, central servers and code repository, high performance computers**

Annual releases

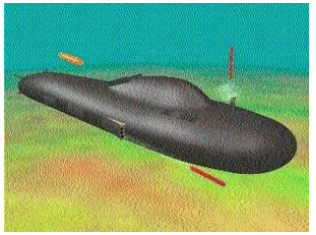
- Increased capability annually
- Extensive beta-tests of each release
- Rigorous V&V process
- Improved scalability for massively parallel computers
- Improved usability
- Responsive to evolving requirements
- Extensive documentation



CREATE--Looking to the Future

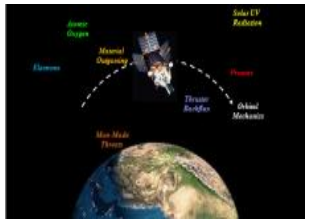
Areas for near-term impact:

- **Hypersonics**: Investments are impacting current and future timeframes (CREATE- AV Kestrel potential)
- **New Submarine Development**: Planning and design work is starting now (CREATE-Ships RSDE potential) with ERS help

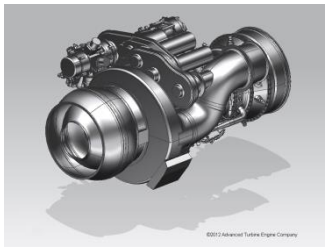


- **Vertical Heavy Lift (JMR-TD)**: Critical capability for the future. Involves both manned and unmanned capabilities. All Service issue for future force structure planning and operational execution. (CREATE-AV Helios has been used for the down-select from 4 to 2 concepts)

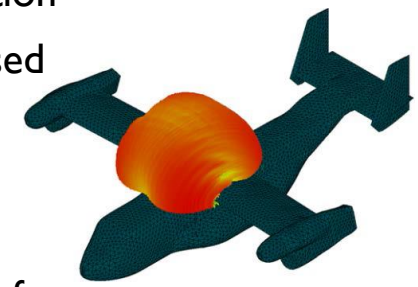
- **Space Technology**: critical design space exploration impacting all Services (e.g. satellites, weapons, sensors, etc.)



- **Improved Turbine Engine Program (ITEP)**: CREATE-AV Kestrel & Helios in use for analysis of engine integration



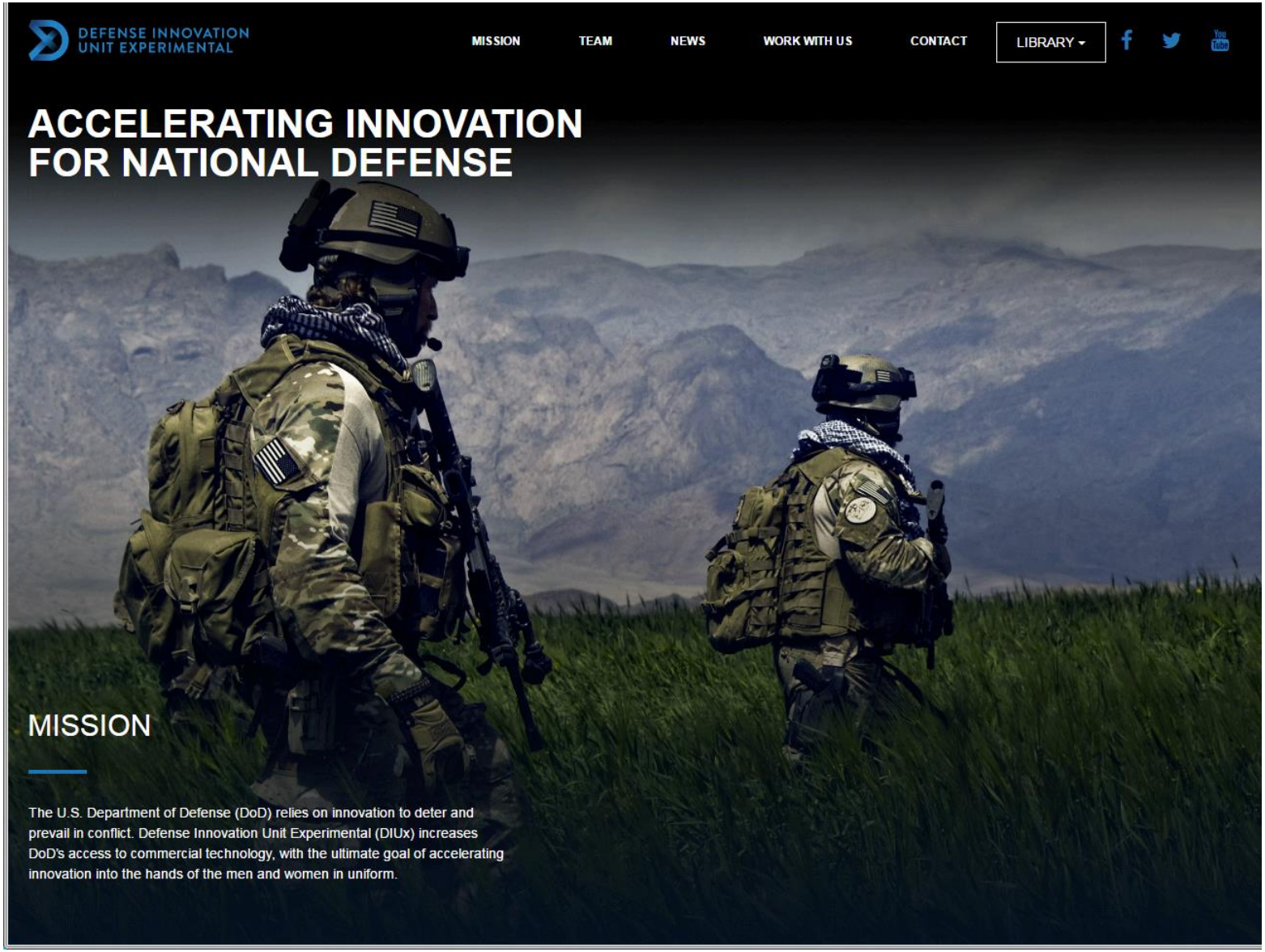
- **EW/Radar/Antenna Modeling**: S-Band, X-Band, Phased Array design analysis electronic warfare opportunities
- **Directed Energy**: Analysis of EM and aerodynamic systems being investigated by Kestrel and SENTRi



- **Service Life Prediction**: Contributes to sustainment of existing DoD systems through advanced mechanics

DoD Seeking Help from Silicon Valley on Innovation

https://www.diux.mil/



DoD Seeks Help from Silicon Valley on Innovation

https://www.diux.mil/

Key Features of Silicon Valley Innovation Culture (Harvard Business Review)

- **Small teams, significant autonomy, empowered to take risks and make decisions**
- **Generally flat organizations, but clear hierarchy**
- **Early Development and Testing of many options**
- **Early Identification of things that work and those that do not**
- **Fanatical pursuit of promising options to a successful conclusion**
- **Leadership continuity**
- **Close working relations and connections with customer communities**
- **Emphasis on incremental improvements and modifications, not huge leaps**
- **Silicon Valley mostly focused on Information Technology with small sized products (smart phones, integrated circuits, music players, computers, calculators …), but:**
  - New Aerospace and Automotive start-ups such as Space-X, Blue Origin, Virgin Galactic, Facebook Aquila, Tesla, Google Car, etc. with industrial scale products retain many of their Silicon Valley roots and features

iPhone was incrementally developed

1993		Newton
1994		120
1998		Apple Message Pad 2100
2005		ROKR
2006		
2007		iPhone (1st generation)
2008		iPhone 3G
2009		iPhone 3GS
2010		iPhone 4
2011		iPhone 4S
2012		iPhone 5
2013		iPhone 5S iPhone 5C
2014		iPhone 6/6+
2015		iPhone 6S/6S Plus
2016		iPhone SE iPhone 7/7 Plus

- Not so easy for DoD
  - Can't build an aircraft carrier in a year
  - But can and must do better

CREATE tools allow DoD engineers and Programs to:

- Design and test many design options quickly
- Take risks, fail early and often, before metal is cut.
- Innovate using much of the Silicon Valley cultural values

Take Aways

- CREATE is providing a set of physics-based engineering modeling tools focused on Service needs in aviation, maritime, ground, and electromagnetic warfare domains
  - Excellent growth potential for CREATE tools in all domains for the future
- CREATE tools: Government-developed, government-owned, and government-supported to meet DoD needs
  - Adoption of CREATE tools is expanding across government, industry, and academic enterprises
  - CREATE tools are the cornerstone of the OSD Engineered Resilient Systems and the Air Force Digital Thread/Digital Twin Programs

CREATE Leadership Team Contacts

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